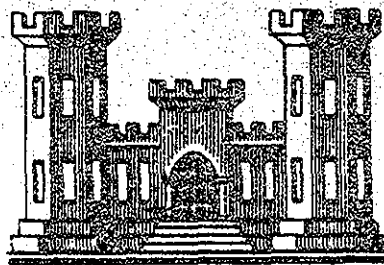


HURRICANE PROTECTION PROJECT

**FOX POINT
HURRICANE BARRIER**

PROVIDENCE RIVER, PROVIDENCE, RHODE ISLAND

**DESIGN MEMORANDUM NO. 13
COOLING WATER AND
CORROSION CONSIDERATIONS**



U.S. Army Engineer Division, New England
Corps of Engineers Waltham, Mass.

JANUARY 1960

U. S. ARMY ENGINEER DIVISION, NEW ENGLAND

CORPS OF ENGINEERS

424 TRAPELO ROAD
WALTHAM 54. MASS.

DRESS REPLY TO:
DIVISION ENGINEER

REFER TO FILE NO. NEDGW

31 December 1959

SUBJECT: / Fox Point Hurricane Barrier, Providence, Rhode Island,
Design Memorandum No. 13 - Cooling Water and Corrosion
Considerations /

TO: Chief of Engineers
Department of the Army
Washington, D.C.
ATTN: ENGWE

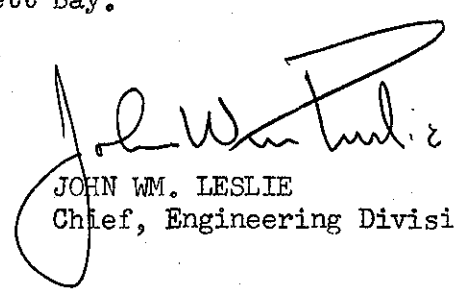
1. In accordance with EM 1110-2-1150 there is submitted herewith for review and approval 10 copies of Design Memorandum No. 13, Cooling Water and Corrosion Considerations.

2. Also forwarded are 10 copies each of Interim Reports No. 3 and No. 4, Model Studies of Narragansett Bay.

FOR THE DIVISION ENGINEER:

2 Incls.

1. Des. Memo No. 13
Cooling Water and
Corrosion Considerations
Fox Point
2. Interim Reports No. 3 & 4
Model Stud. Narragansett Bay



JOHN WM. LESLIE
Chief, Engineering Division

FOX POINT HURRICANE BARRIER
PROVIDENCE
RHODE ISLAND

DESIGN MEMO NO. 13

COOLING WATER AND CORROSION CONSIDERATIONS

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2	Hydrology Preliminary Final	3 June 1959 17 Nov 1959	8 June 1959
3	Deleted		
4	Hurricane Tidal Hydraulics		
5	General Design Memo	22 Dec 1959	
6	Embankment & Foundations		
7	Structural Section I		
8	Structural Section II		
9	River Gates		
10	Pumping Station		
11	Cooling Water Canal		
12	Sewer & Utility Modifications		
13	Cooling water and Erosion Considerations		
14	Concrete Materials	3 Nov 1959	27 Nov 1959

FOX POINT HURRICANE BARRIER

DESIGN MEMORANDUM NO. 13

PROVIDENCE RIVER

COOLING WATER & CORROSION CONSIDERATIONS

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U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
424 TRAPELO ROAD
WALTHAM 54, MASSACHUSETTS

FOX POINT HURRICANE BARRIER

PROVIDENCE RIVER

RHODE ISLAND

DESIGN MEMORANDUM NO. 13

COOLING WATER AND CORROSION CONSIDERATIONS

JANUARY 1959

A. INTRODUCTION

1. Purpose. The purposes of this design memorandum are as follows:

- a. To describe and record existing conditions in the Providence River, particularly in relationship to the cooling water usage of the Narragansett Electric Company's Manchester Street and South Street steam power plants.

- b. To ascertain the extent and effect of changed conditions, both favorable and unfavorable.

- c. To state the opinions of the New England Power Co. with respect to the possible detrimental effects of the barrier on operations of the Narragansett Electric Co. and its views as to measures required to counter detrimental effects.

- d. To recommend measures for protection of the utility.

2. Introduction. The Fox Point Hurricane Barrier will be constructed across the Providence River in the City of Providence, Rhode Island. The barrier will be downstream of the intakes and discharges of the condenser cooling water system of two Narragansett Electric Company power plants. This utility is a subsidiary of the New England Power Company.

The normal operations of the power plant increase the river temperatures appreciably, and corrosive elements in the water and bed materials are a constant problem to the power company.

3. General Description of Providence River. The Providence River, a tidal estuary flows from the confluence of the Moshassuck and Woonasquaket Rivers into Narragansett Bay.

The river is only 3/4 of a mile long and varies in width as it flows through the center of Providence from about 140' near the Crawford Street bridge to 800' at its confluence with the Seekonk River.

The river water is naturally a mixture of fresh and salt water with a considerable load of industrial, sanitary and storm sewage. The pollution and decomposing organic silt cause the water in the vicinity of the project to be corrosive.

The upstream tributaries carry a very fine grained organic silt, which is deposited in the still waters of the estuary. The top layer of the deposit is very fluid in character and subject to erosion by any slight increase in current. The process of decomposition is active in this stratum.

B. INVESTIGATIONS

4. Necessity and extent.

a. Necessity. (1) Special Construction. The provision of access to a source of cooling water below the barrier and of special construction measures for the protection of Narragansett Electric Co. is a special item of appreciable expense. The subsequent maintenance of the cooling water canal wall will be relatively high in cost. It is necessary to determine the need for the special provisions.

(2) Record of Existing Conditions

The New England Power Company has taken the position that special construction measures are not considered assurance of adequate protection for its facilities, that actual experience will be the criterion. Thus it becomes necessary to establish existing conditions of the Providence River for reference in case damage claims are made.

(3) Relationship to Local authorities

The Narragansett Electric Company plant and the local authorities, particularly the City of Providence, will be parties to any financial settlements, with an unusual variety of considerations. Directly, the Barrier right-of-way will be located across the Narragansett Electric Company property. The Narragansett Electric Company will supply power, particularly for operation of the pumping station. The plant will be a unit of a contemplated special assessment district, which will be required by the local enactment to pay 10% of the cost of the Barrier.

The operation of the cooling water canal is of mutual interest to the City and to the utility. The City desires that every effort be made to hold costs to the lowest safe amount in design of the project. Some officials have informally questioned the need for the canal, and there

is realization of the evident benefit to the utility in the improvement of cooling water temperatures the canal will provide.

These interrelated considerations require all reasonable care in establishing conditions in the river and in determining the need and affect of the various features with respect to the Narragansett Electric Co. plant.

(4) Other

The investigations will serve also to aid in designing the Barrier for corrosive river water characteristics and in forecasting future effects upstream of the Barrier.

b. Extent of Investigations. The investigations included the following:

- (1) Extent of Silting
- (2) Analyses of water and river bed materials
- (3) Rate of settlement
- (4) Record of river water temperatures (26 August to 11 Sept. 1959)
- (5) Current measurements (26 August to 11 Sept. 1959)
- (6) Records of intake and discharge cooling water volume and temperatures, power output, tides, barometric pressures, and air temperatures. (26 August to 16 September 1959).
- (7) Record of condenser tube failures and of corrosion of sheet piling.

5. Silting.

a. Present Conditions. The river is gradually filling with silt and is shoaling progressively from the upstream end. Before 1900 there was a "Cove" area above Crawford St. Bridge which was used as an anchorage. According to local information silting was an ever-present problem. After abandonment of the "Cove" a 30-ft. ship channel was maintained to the slips below Crawford St. Bridge. No dredging for navigation has been carried out since a survey in 1939. The estuary has since been reduced to a shallow river channel almost to the upstream cooling water intakes of the Narragansett Electric Company. The depth of deposits since 1939 has reached a maximum of 15 ft. below Crawford St. Bridge. Some silting has occurred in the area abreast of the power plant, averaging about 2 ft. in thickness. See Plate 13-2 for extent of silting. The utility company has dredged in front of the intakes, most recently in 1952 and 1955. This dredging has been partially to clear the intakes and partially to deepen the channel.

b. Rate of Deposition. The quantity of silting is estimated at 160,000 c.y. which averages 8,000 c.y. per year.

c. Odor Nuisance. The shoal area near the Crawford St. Bridge is exposed at low tide. Because of the high content of decomposing organic material it creates a marked odor nuisance.

d. Future Silting. The effect of the barrier on the rate of silting cannot be stated with certainty. Apparently the greater proportion of transported silt now deposits as soon as it is carried into slack water at the head of the estuary. Since the greater portion of deposition over the past 20 years has been at the head of the estuary, no appreciable increase in the rate is expected.

6. River Bed Materials

a. Description. The top stratum in the river is a gray to black organic silt (OH) about 20 feet thick. The uppermost 5 feet of this stratum has a very soft consistency as evidenced by the penetration of A-rod probes (1-5/8" Outside Diameter) under its own weight (approximately 115 pounds). An attempt was made to run shear tests on undisturbed samples obtained from the uppermost 5 feet, but the sample slumped under its own weight while it was being ejected from the sampling tube. The unconfined compressive strength of the material below the top five feet ranges from 0.2 to 0.5 tons per square foot. In general, the top 5 feet of the organic silt contains 70 to 90 percent by weight particles having a diameter smaller than 0.074 millimeters and ten percent by weight of the material has particles with grain sizes smaller than 0.0025 millimeters in diameter. The natural wet density ranges from 69 to 105 pounds per cubic foot. The organic contents determined by burning tests range from 5 to 20 percent. Liquid limits range from 65 to 159. Plasticity indices range from 29 to 108. Natural moisture contents varied from 45 to 255.

Below the uppermost 5 feet the same type of material has been consolidated to a more solid condition and organic content is less.

b. Settlement Time. A sample of the river bed materials was thoroughly agitated in an 18" beaker. The disturbed sediment settled completely in 8 minutes. See Exhibit 13-6.

7. Past Experiences with Corrosion.

a. Measurement of Piling Corrosion. Measurements were made to establish amount of corrosion of 2 sheet piling driven at the water front at the Manchester St. Station intake screen house. The piling was installed in 1940. These measurements have not extended below the water line. They show that serious corrosion has occurred near the low water elevation, where the thickness has been reduced from .375 inches to an average of .215 inches.

b. Failures of Condenser Tubes. Representatives of the New England Power Company in conversations with this office have stated that the normally corrosive character of the river water has been a source of continual concern because of the high rate of condenser tube failures with resultant loss of boiler efficiency and necessity for retubing. At present, several alloys of cupronickel are used which are fairly satisfactory. See Exhibit 13-7 for composition of alloys.

It was also stated that during the construction of a new expressway in 1955, across the river upstream of the plant, a higher rate of failures occurred, and that upon complaint the method of excavation was improved. Information from the Rhode Island Public Works Department confirms the fact that complaints were received and methods of excavation were changed to minimize slopping of excavated slit into the river water.

The following record of excavations was obtained:

East Bulkhead. Excavated without sheet pile protection,
27 April - 12 May 1955.

West Bulkhead. Excavated largely without sheet pile protection, 19 May - 10 Sept. 1955 and 29 Sept. - 7 Oct. 1955. This bulkhead is near the deep channel of the estuary. Complaints were received from the New England Power Company. More care was exercised in handling the mud and afterwards no complaints were made.

Piers. Excavated inside cofferdams, 4 May - 20 July 1955. There were other excavations later behind cofferdams, or in the Old Dorrance Street slip. No complaints were received.

A chart of condenser tube failures was furnished by the New England Power Company and the record has been shown herein in Plate 13-4.

c. Dredging. The Narragansett Electric Company has dredged in front of the cooling water intake at intervals to remove silt or deepen the channel most recently in 1952 and 1955. In 1955 about 11,000 c.y. of silt was removed. Officials state that no special precautions were taken

and no ill effects noted. They have no clear opinion as to the reason and there was no noticeable increase in rate of tube failures following the work.

8. Analyses of Water and Bed Materials.-

Samples of the river water were taken near the surface and near the bottom. They were taken at low tide, at mean tide, and at high tide. Samples of the top stratum of river bed materials were taken at the barrier site at 3 locations across the river. Other river bed samples were taken at greater depths at the middle of the river.

These samples were analyzed for chemical and bacteriological content. The Reports and results are given as Exhibit No. 13-8.

In brief, it was found that positive values for sulfides were found in only three of the water samples. The chemist did not consider that sulfides in the water will be a very great corrosive factor, but dwelled on the high chloride content as being a more important factor. The chloride content is about 16,000 parts per million, in comparison with a content of about 32,000 parts per million at the mouth of Narragansett Bay.

9. Existing Currents and Tides.-

a. Extent of Investigation. A record of existing river contamination, temperature and currents was made by the U.S. Coast and Geodetic Survey and the U.S. Public Health Service during the period 26 August through 11 September 1959. Readings were taken daily over the entire estuary at levels 3 ft. from the surface, mid-depth and 3 ft. from the bottom. Additional around-the-clock 50-hour readings were taken at three locations.

b. Current Data. Data on currents at mid-depth and near the bottom are given below. Current readings near the surface are not so reliable because of gross variations due to magnetic effect of the ship on the metering instrument and are not shown.

	<u>Mid Depth</u>	<u>3 feet above bottom</u>
Station 1	0.30 knot, max., downstream 0.05 knot, average "	0.20 knot, max. upstream 0.02 knot, average "
Station 2	0.40 knot, max. downstream 0.02 knot, average "	0.30 knot, max. upstream 0.06 knot, average "
Station 3	0.30 knot, max. downstream 0.10 knot, average "	0.50 knot, max. upstream 0.07 knot, average "

Note: One knot equals 6,080 ft. per hour or 1.69 ft. per second

Current readings do not show a reversal of flow for ebb and flood tides, although there is an indication of slackened upstream current at the bottom during ebb tide. For location of stations see Plate No. 13-3. For reproduction of current records see Plate No. 13-5.

c. Tidal Action. The average tidal range is between + 2.47 msl, and -2.13, msl. Greater ranges are reached at frequencies as tabulated below:

<u>Period of Frequency</u>	<u>Elevation Equalled or Exceeded (msl)</u>	
	<u>H.W.</u>	<u>L.W.</u>
Weekly	3.8	-2.9
Monthly	4.3	-2.9
Yearly	5.5	-4.2
Ten Year	6.2	-5.1

During the run of the tide the surface elevation changes about one foot per hour at Manchester St. Station. Based on the estuary basin volume this would induce an average ebb and flow of 300 c.f.s. and an average velocity of .024 ft/sec. or 85 ft. per hour.

d. Upstream Inflow. The average high water inflow from the tributary land area is about 400 c.f.s. Low flow is approximately 40 c.f.s. During the period of the recent river readings, estimated inflow was 55 c.f.s. This estimate is based on an average recorded flow of 28 c.f.s. for the dates of 26-27 August at the gage at Centerville, R.I. from a drainage area of 38 sq. mi. Low water flow is obviously insignificant in effect on currents and temperatures.

e. Cooling Water Flows. The cooling water usage of the Narragansett Electric Co. during this period was as follows:

	<u>Condenser No.</u>	<u>Quantity c.f.s.</u>	<u>Elevation of Intake m.s.l.</u>
Manchester St. Station	9,10,11	380	-11.25
South St. Station			
South intake	1,7	235	-19.5
North intake	8	<u>200</u>	-19.25
	Total	815	

The quantity varies with power requirements and temperature changes. Future requirements may increase the amount to about 1,000 c.f.s.

There are four condenser discharges with elevations and maximum discharge quantities as follows:

	<u>Condenser No.</u>	<u>Max. Quantity cfs</u>	<u>Discharge Invert El. (msl)</u>
Manchester St.			
South	10,9 (part)	200	-2.5
North	11,9 (part)	250	-4.5
South St.			
South	7	150	-12.5
North	1,8	<u>290</u>	- 3.5
	Total	890	

10. Existing Temperatures.

a. Temperature Readings. Temperature readings of the river water were taken for the period 26 Aug.-11 Sept. 1959 by the U.S. Coast and Geodetic Survey and the U.S. Public Health Service. Hourly records of barometric pressure, air temperature, tide levels, intake and discharge temperatures of the cooling water, and power output for the period, 26 Aug.-16 Sept. 1959, were furnished by the New England Power Co.

b. Air Temperatures. Air temperatures ranged from a high of 95° on 28 August 1959 to a low of 45° on 16 September, but were within a narrow range of daily fluctuations until 11 September.

c. Barometric Pressures. Barometric pressures were obtained. The slight changes of tide levels had no significance in water temperatures.

d. Cooling Water Temperatures. Condenser intake and discharge cooling water temperatures have been plotted in relation to air temperatures, tides and power output as shown on Plate 13-4. There is one intake for the 3 condensers at Manchester St. The cooling water temperatures for the condensers have been averaged. At South Street Station the intake for condenser No. 8 is apparently greatly affected by recirculation of discharge water, temperatures averaging several degrees higher than the river bottom water at that point and fluctuating widely, and it has been plotted separately.

Some characteristics of intake temperatures during this period were:

(1) Temperatures dropped promptly when a cool period of air temperature occurred, probably due to increased surface cooling of the river water.

(2) Temperatures were slightly higher at low tide, particularly at South Street Station.

(3) Temperatures increased with sustained higher power output.

(4) Temperatures were consistently higher at Manchester Street Station, which has a higher intake.

e. River Temperatures.

River temperatures were taken daily for the period 26 August to 11 September 1959 over the entire area of the estuary. Additional readings were taken on an around the clock basis for a 50-hour period.

In order to depict the temperature conditions some of the readings have been plotted and tabulated. Water temperatures 3 ft. above the bottom are tabulated below. Continuous readings are plotted against tides and power output in Plate 13-3. Temperature contours of the river for 27 Aug. and 31 Aug. are also plotted on Plate 13-3.

Some deductions made from the above charts are as follows:

a. Temperatures do not show any apparent change with ebb and flow of tide except at the Seekonk River. At the Seekonk River a slight rise of about 2° coincides with low tide conditions.

b. Temperatures generally build up as power output is increased and maintained during the working days of the week.

c. Temperatures rise progressively up the estuary.

d. Temperatures opposite the South Street plant average 4.6°F higher than at the Seekonk River and show sudden sharp peaks of higher readings more frequently at low tide.

PROVIDENCE RIVER
WATER TEMPERATURES 3 FT. FROM BOTTOM
DEGREES FAHRENHEIT

<u>Date</u>	<u>Location</u>			
	<u>Seekonk River</u> (Sta. 2.)	<u>Manchester St.</u> (Sta. 13)	<u>South St.</u> (Sta. 21)	<u>Upper End</u> (Sta. 26)
25 Aug.	71.6	75.9	76.6	83.3
26	72.5	75.0	77.4	81.1

Date	Seekonk River (Sta. 2)	Manchester St. (Sta. 13)	South St. (Sta. 21)	Upper End (Sta. 26)
27 Aug	73.9	75.6	-	-
28	74.8	75.4	75.2	85.8
29	(Week end)			
30	" "			
31	71.6	74.7	76.1	81.0
1 Sept	72.1	73.0	75.7	77.4
2	73.2	73.9	84.6	80.6
3	73.7	79.2	81.0	79.6
4	72.5	74.5	77.7	81.0
5	(Week end)			
6	" "			
8	73.8	76.0	78.3	86.0
9	75.7	74.5	76.1	87.3
10	74.8	73.8	76.1	80.2
11	72.1	72.7	79.9	80.2
Avg	73.3	75.0	77.9	81.9

C. MODEL STUDY OF TEMPERATURE EFFECTS

11. Cooling Water Temperature Studies.

a. General. Model studies were undertaken to give an indication of the effect of the barrier on the cooling water temperatures. These were conducted at the Waterways Experiment Station using the model of the Narragansett Bay which had been set up for hurricane tide studies. Tests were run to establish the following conditions:

- (1) Existing conditions as a reference.
- (2) Effect of the barrier, assuming no special cooling water canal was provided.
- (3) Effect of the barrier, with cooling water canal provided.
- (4) Construction cofferdam sequences as affecting the cooling water temperatures.

The model tests simulated existing tidal flow, salinity, cooling water demands and temperatures, and upstream flow. Both average high water and low water upland inflows.

b. Existing Conditions. The following statement on existing conditions is quoted from Interim Report No. 3 of the Waterways Experiment Station. "While not entirely pertinent to the purpose of the model tests, data obtained during the exploratory tests and the base tests indicate that the present circulation of cooling water has an appreciable effect on water temperatures throughout the problem area. During the exploratory tests, which did not simulate circulation of cooling water, it was found that the average

water temperature in the problem area was 1° less than the fresh water temperature. In the base test, which simulated the existing circulation the average temperature was 4.2°F higher than the fresh-water temperature, or an increase in average temperature of about 5.2°F because of the circulation of water at the power stations.

c. Barrier without Cooling Water Canal. The following discussion of the effect of the barrier without a cooling water canal is also quoted from Interim Report No. 3: "The results of the model indicate that the Fox Point barrier would reduce vertical circulation between that portion of the Providence River downstream from the structure and that upstream where the cooling water intakes and outlets are located, and the reduced vertical circulation would cause an increase in the average water temperature of the upstream area by 3.0°F to 3.5°F. The tests also indicate that the temperature of the intake water at the South St. Station would be increased by less than the average. This difference is attributed to the fact that the South St. intake is appreciably deeper than the Manchester St. intake, which lessens the effect of the reduced circulation.

"The tests also indicate that the reduced vertical circulation would cause a slight reduction in water temperature downstream from the barrier, as evidenced by temperature measurements at Station 19. It therefore follows that any scheme for drawing cooling water from the downstream area would provide cooler water to the plants with the barrier installed than would be available without the structure." (Station 19 in the model is at the confluence with the Seekonk River).

Representatives of the New England Power Company have stated informally that present cooling water temperatures are critically high during hot summer weather, that loss of power as high as 7% has been experienced, and that higher temperatures would cause additional losses.

d. Barrier with Cooling Water Canal. The following discussion of the effects of the barrier with a cooling water canal are quoted from Interim Report No. 4. (This condition is termed "Plan No. 3" in the Report).

"The results of the model tests of Plan 3 indicate that all detrimental effects of the Fox Point barrier on cooling-water temperatures would be eliminated by this plan. The average intake temperature at the Manchester St. Station would be significantly lower than that for existing conditions, while the average temperature at the South St. intake would be no higher than for existing conditions. On an over-all basis, the quality of the cooling water available to the Narragansett Electric Co. would be significantly better after completion of the barrier and the Plan 3 cooling-water channel than for existing conditions.

"While not tested in the model, it is believed that the indicated improvement in water quality over existing conditions (as affected by Plan 3)

would be even greater if the quantity of water circulated should be increased as is contemplated. This opinion is based on the rather large reduction in average surface temperatures at the plan intake locations as compared to the temperatures at the existing intake locations (-4.4F at the Manchester St. intake and -5.2 F at the South St. intake). If the quality of water circulated should be increased appreciably, it appears that the additional water drawn into the intakes would be warmer under existing conditions than under Plan 3 conditions.

The results of the tests indicate that Plan 3 would increase the average water temperature upstream from the barrier by about 3.4°F; however, this increase would be of little or no significance unless other plants obtain cooling water from the affected area."

e. Recirculation below barrier. Representatives of the New England Power Co. have informally expressed a firm opinion that the cooling water canal wall should be extended downstream to guard against intake of corrosive elements during construction from a fear that recirculation of the warm discharge water will otherwise occur to a marked extent. Currents are too sluggish to reproduce in a model and obtain satisfactory conclusions on recirculation. Results of the model study with the cooling water canal show that the overall effect of the project is beneficial.

f. Construction Period. It is assumed that the construction will be in a two-stage cofferdam operation and will considerably reduce the present river cross-sectional area during the construction period. A model study for an initial stage cofferdam inclosing the pumping station and west abutment, thereby restricting the river to the east side, showed that the South Station would not be noticeably affected, but that intake temperatures at the Manchester Street Station would rise as much as 3°F.

D. VIEWS OF NEW ENGLAND POWER COMPANY

12. Views of New England Power Company.- The Narragansett Electric Company, a subsidiary of the New England Power Co. operates 2 steam power plants on the right bank of the Providence River. It has a nominal capacity of 363,000 KW. It draws condenser cooling water from the river and discharges the heated water back into the river. The present usage is about 815 cfs. Intakes are placed at as low as possible and discharges are near the surface. Locations of intakes and discharges are shown on Plate No. 13-1.

The attitude of the N.E.P. Co. with respect to the plant and to the construction of the Barrier is given in these quotes from a letter of 1 April 1959:

"In the broad picture it must be recognized that the Narragansett Electric Company's steam-electric site on the Providence River

is ideally located to deep draft navigation facilities for fuel transportation. Recognizing the inevitable growth in electric power needs for the area, which indicates a doubling of load in each succeeding ten or fifteen years, it is obvious that a utility company must not only be foresighted in acquiring power house sites for future development, but must be equally conscientious in preserving the advantages of existing sites. In the case of the Providence River site, this means maintaining the area for the efficient operation of the existing facilities as well as preserving this favorable area for future changes and expansions."---

"It is of great concern to us that every possible precaution should be taken to prevent temperature rise in the circulating water used in the plants and the contamination of the circulating water during construction.----

"We firmly believe that liveable cooling water conditions can only be assured by construction of an intake channel as included in your 1957 Interim Report. We also feel that this channel, and an entrance structure built behind a coffer dam, should be the first stage of river construction. From our experience we know that the disturbance of the river bottom by excavation during construction will cause the release of sulfides and other substances which will rapidly destroy the tubes ordinarily used in condensers. Unless such a channel were provided as a first step, and excavation made back of coffer dams, we would probably have to re-tube the condensers with stainless steel prior to the start of construction, at a very substantial cost.

"We also believe that the existence of the barrier would result in some temperature build-up behind it. Model studies may give a qualitative indication of this, but we feel it is impossible to predict the extent to which future silting and shoaling will influence current distribution and water temperatures.

"The rate of silting in the Providence River may also be accelerated and even if the rate does not change, it is difficult to see how it would be possible to dredge in front of our intakes and dispose of the material in any practical manner, due to limitations imposed by the barrier."---

In a later letter dated 14 September 1959, the cost of re-tubing is estimated at \$637,064. The letter stated that there would be an estimated outage per unit of 3 weeks, during which there would be a substantial cost of power replacement.

E. DISCUSSION AND RECOMMENDATIONS

13. Cooling Water Canal. a. Necessity. The records of existing conditions indicate the sensitiveness of condenser intake water tem-

peratures to changes in power output and to atmospheric temperatures. The model studies show that existing water temperatures upstream of the barrier site would be raised by an average of 3.5° if no canal were provided. This would result in a corresponding loss of efficiency, particularly in the warm season of the year. Provision of a canal to protect water temperatures is therefore considered justified and is recommended.

b. Description and Cost. The cooling water canal would be formed by a wall of soldier H-beams and timber panels. Intake flow would be controlled by gates located in the pumping station. Discharges would be carried by flume extensions across the canal to the upstream barrier pool. The estimated cost is \$1,121,000.

14. Protection against Corrosive Elements.-

The New England Power Company has stated that there was increased damage of condenser tubes with subsequent failures due to disturbance of the river bottom during construction of the upstream expressway. Based on this experience the company considers that the excavation for the barrier, which will be of greater magnitude and will be across the approaches to the condensers, will result in great damage unless protective measures are taken.

Available information does not conclusively show increased tube failures coincident with past excavations. Nor do chemical analyses and the silt settlement rate show that excavation for the barrier would increase sulphide concentration in the water long enough to be carried to the condensers.

The present tube compositions are selected after long experience as most resistant to normal river water composition, which is predominantly saline.

Sulphide gas is released from the water in quantity in warm weather, but it is not apparent that the concentration in the water is sufficient to cause increased tube failures in the summer. It is recognized that the cupronickel alloys of the tubes are not resistant to sulphide action.

Care in excavation will reduce damage, or the possibility of damage, and is considered of vital importance. Measures which will be adopted include excavation in cooler weather, if practicable, excavation in the canal within enclosed areas except in front of the intakes, and a temporary extension of the canal wall. These measures will exclude the disturbed materials to a maximum extent from the canal. They will increase the length of time in which the sulphide elements will pass from the point of excavation to the condenser tubes and thus allow the sulphide gas a maximum time in which to escape from the cooling water. The cost of the downstream wall extension is estimated at \$115,000.

15. Other Changes.-- The construction of the canal will provide an intake further downstream than at present. This may result in a slightly more saline water because the salt concentration increases gradually in a downstream direction. Also the intake of suspended sediment may be slightly less.

As the canal velocities will be higher than present, and as it is not possible to completely remove and replace the top layer of river bed materials in the canal bottom, intake of sulphides may be increased until the bottom reaches a new equilibrium with the current.

The effect, if any, of these changes cannot be presently evaluated.

16. Future damages and Benefits to New England Power Company.

a. Benefits. Model studies indicate that construction of the cooling water canal will improve cooling water temperatures. Measurement of the value of this betterment would depend on records of temperatures before and after installation of the canal and would require an extensive study of plant operations.

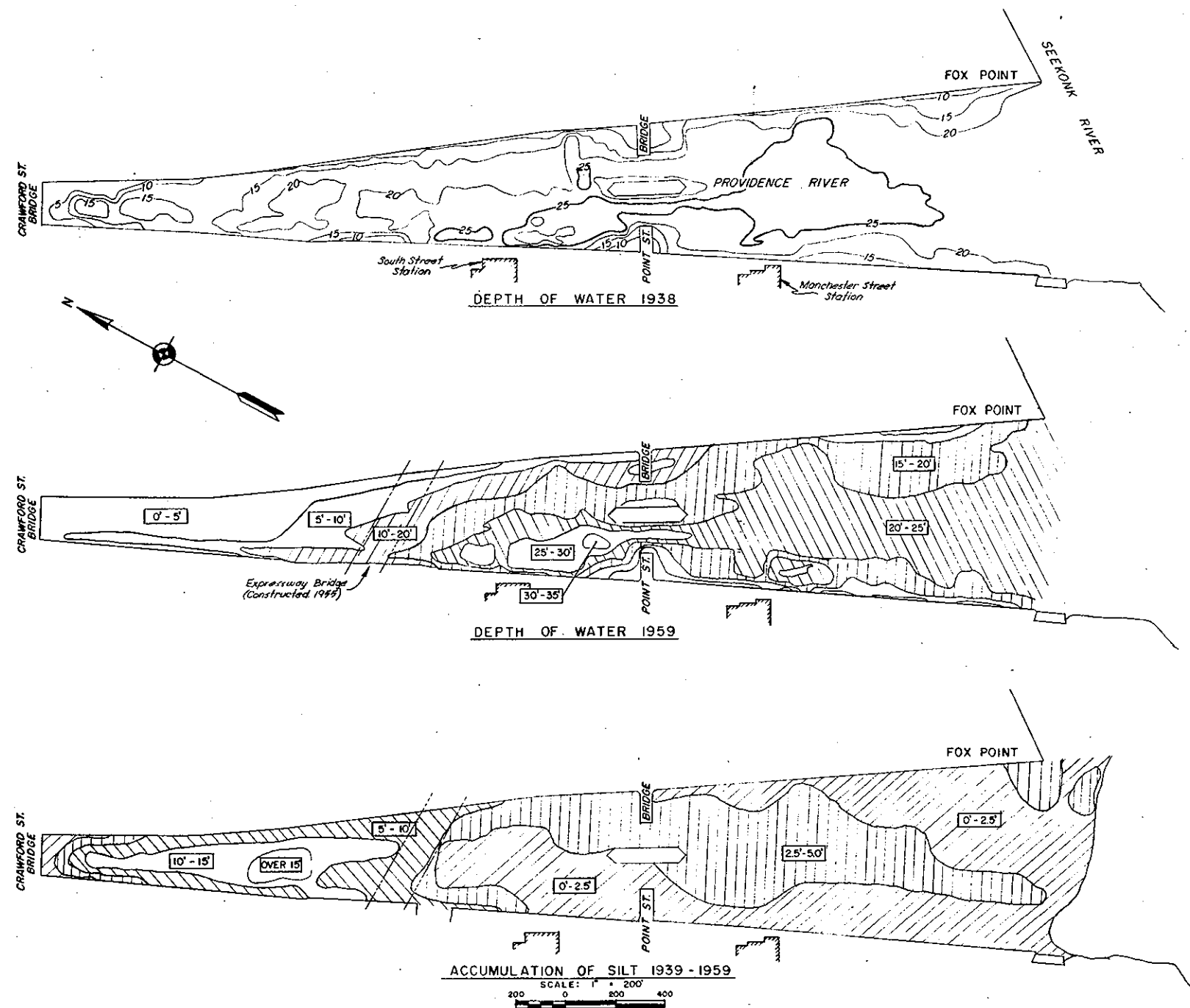
b. Damages.

Damages would be indicated by an increased rate of experienced tube failures and of retubing. Present analyses of river water will be useful reference in future weighing of damages if claimed. Analyses will be made during the construction period for record of changed chemical composition of the water.

17. Upstream Pool. a. Changed Conditions. It is noted in the preceding paragraphs that silting will continue upstream of the barrier, and that average temperatures will be higher.

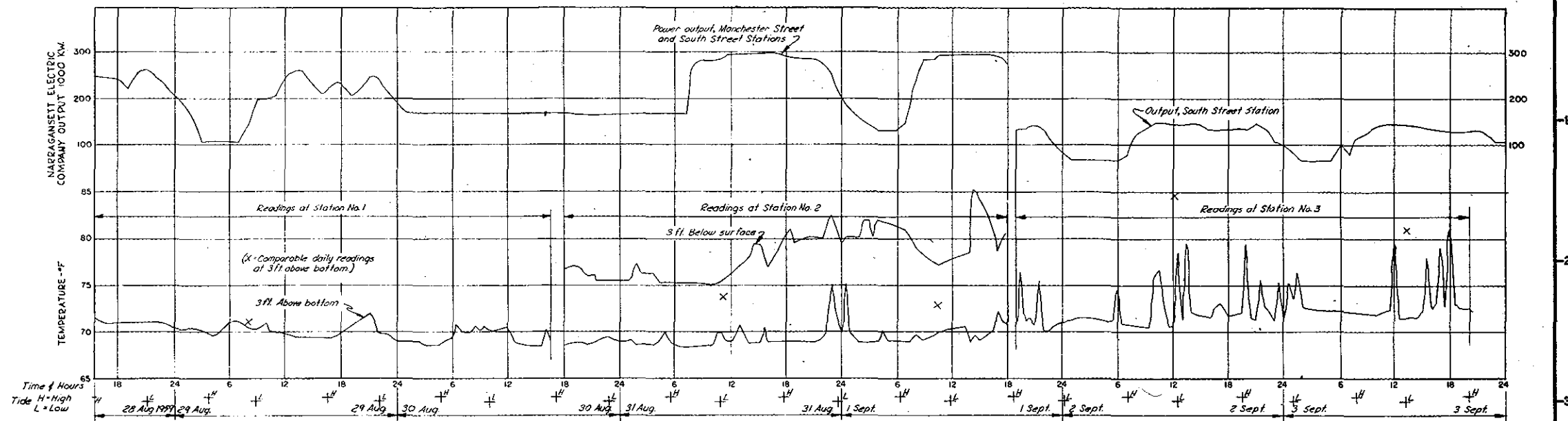
b. Dredging. There is no present dredging except for maintenance of the present cooling water channel. Construction of the proposed canal will eliminate this need. Development of the pool as a marina is not locally desired as there are ample anchorages in less polluted waters. Dredging to clear pumping station intakes may be carried out from the trash deck. Therefore there will be little, if any, need for marine dredges.

c. Odor Nuisance. There has been considerable attention to the odor nuisance from the tidal flats, without action to date. The condition may be aggravated by higher temperatures. The most feasible remedy appears to be excavation to a depth below low water. Because of the constricted area of the present mud flats, and the location of the expressway, marine dredges cannot operate in the area, but draglines can be used, working from the river banks.

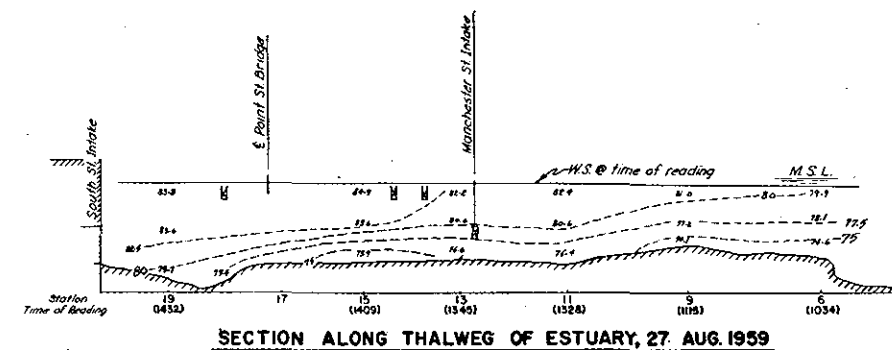
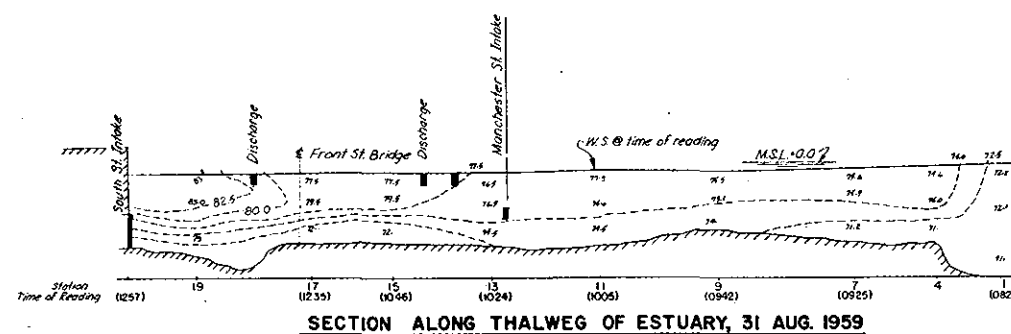


NOTE:
Elevations refer to Mean Sea Level datum

REVISION	DATE	DESCRIPTION	BY
U.S. ARMY ENGINEER DIVISION, NEW ENGLAND CORPS OF ENGINEERS WALTHAM, MASS.			
FOX POINT HURRICANE BARRIER			
PROVIDENCE RIVER SILTING			
PROVIDENCE		RHODE ISLAND	
APPROVAL RECOMMENDED		DATE DEC 1959	
CHIEF, R.E.D. BRANCH		CHIEF, ENGINEERING BRANCH	
SCALE: 1" = 800'		SPEC. NO. C	
DRAWING NUMBER		FP-1-1016	
SHEET 2			



WATER TEMPERATURES
AROUND THE CLOCK READINGS

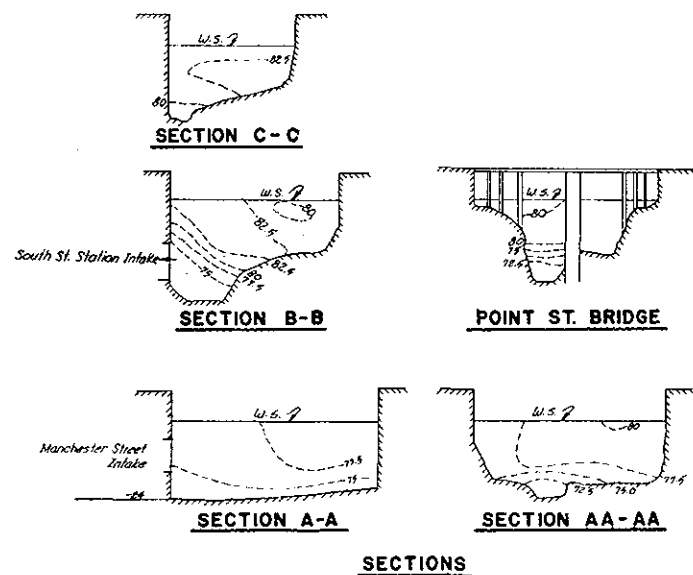
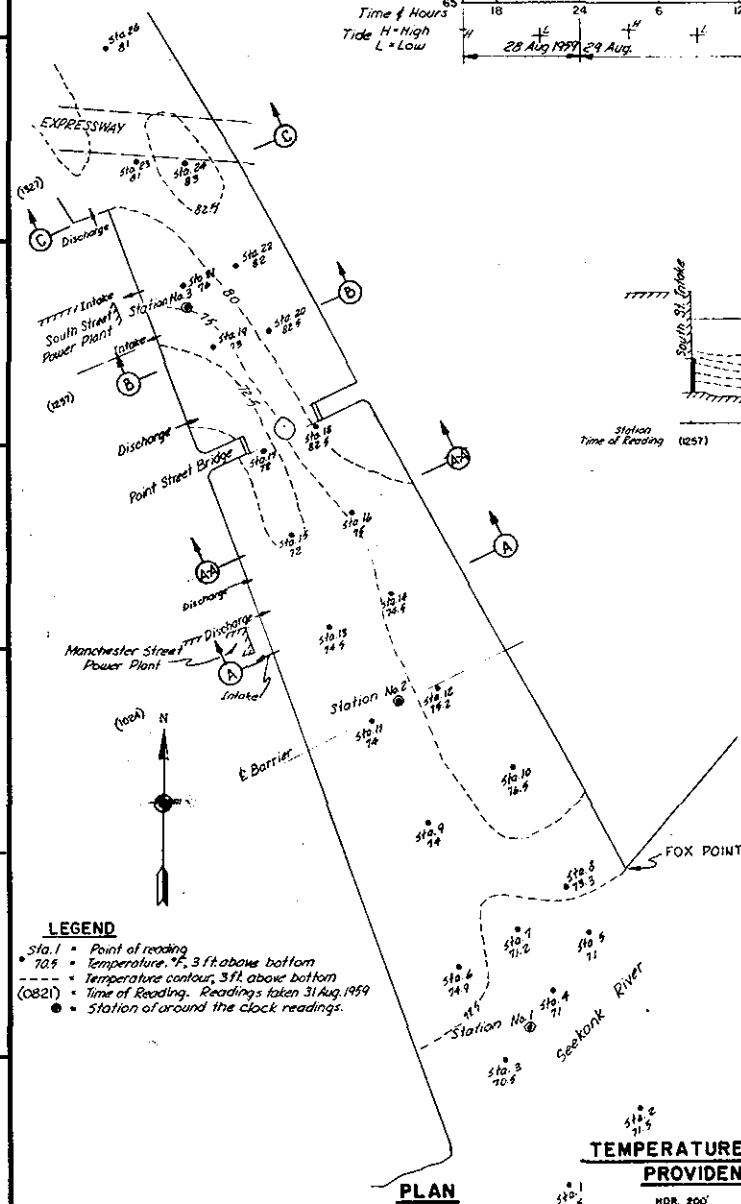


NOTE:

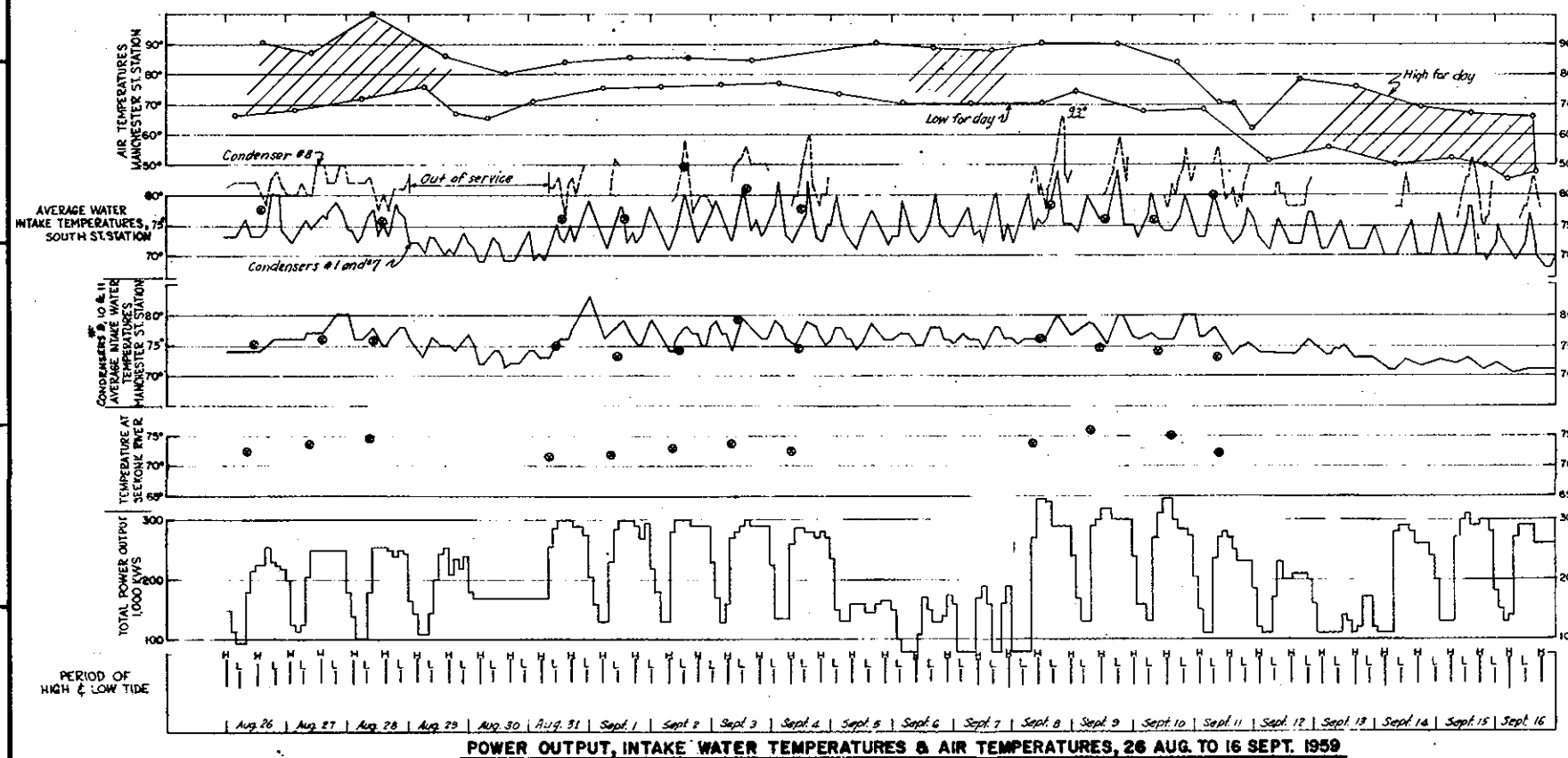
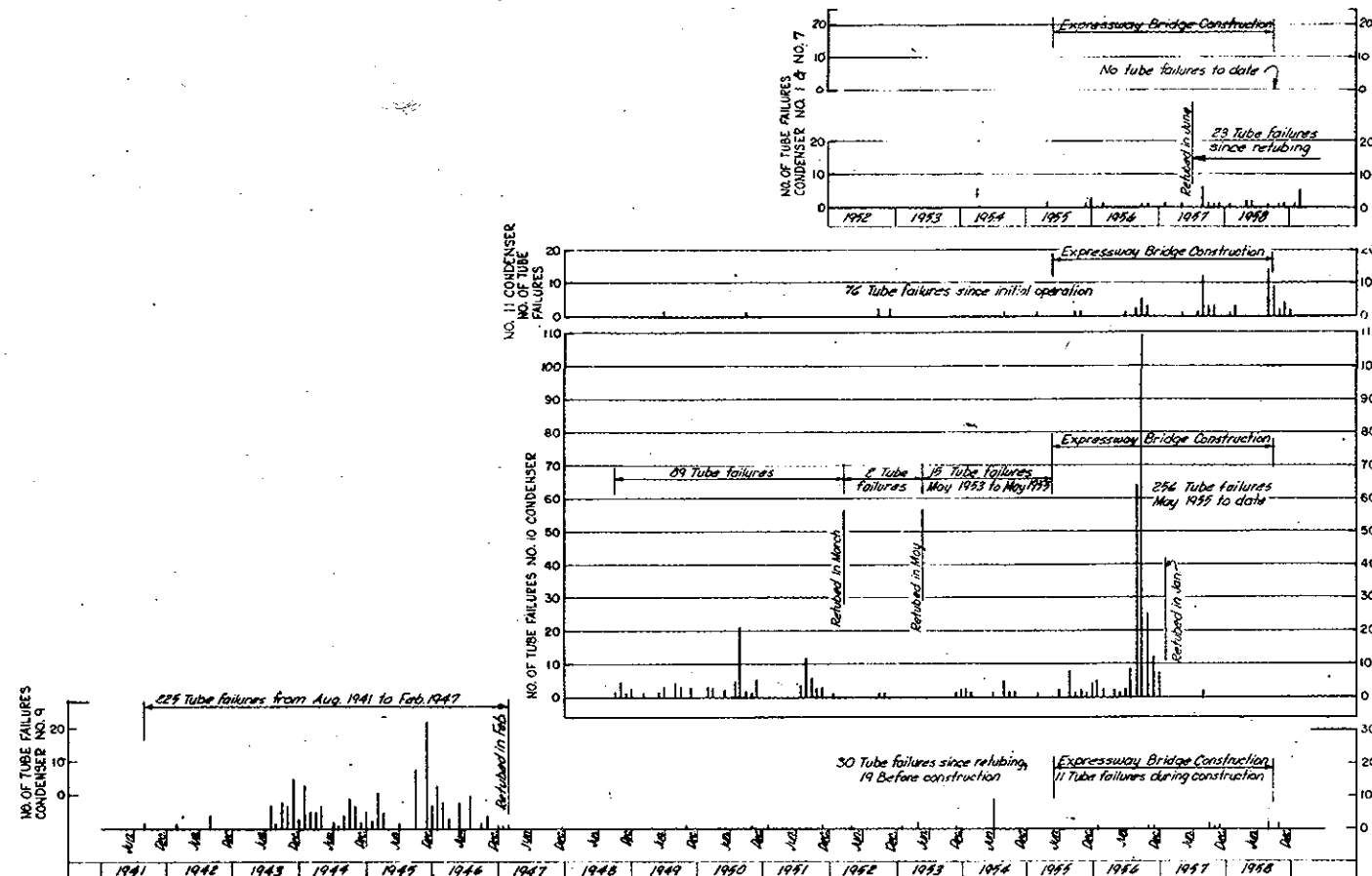
Readings of 31 Aug. 1959 were taken near low tide after weekend period of low power production. High tide of 10:04.
Readings of 27 Aug. 1959 were taken near high tide near end of weekly period of normal power production. High tide at 1436.

NOTES:

Temperatures taken at 3 stations around the clock by U.S. Coast and Geodetic Survey, 28 Aug. - 3 Sept. 1959.
Temperatures taken over estuary on daily basis, by U.S. Public Health Service - Aug. 26 to Sept. 1959.
Power output furnished by Narragansett Electric Co., 26 Aug. - 16 Sept. 1959.



U.S. ARMY ENGINEER DIVISION, NEW ENGLAND CORPS OF ENGINEERS WALTHAM, MASS.			
FOX POINT HURRICANE BARRIER			
PROVIDENCE RIVER TEMPERATURES			
PROVIDENCE RHODE ISLAND			
APPROVAL RECOMMENDED		APPROVED	
DATE		DATE	
DEC. 1959		DEC. 1959	
CHIEF, P. & B. BRANCH		CHIEF, ENGINEERING DIVISION	
SCALE: AS SHOWN		SPEC. NO.	
DRAWING NUMBER		SHEET 3	
FP-1-1017			

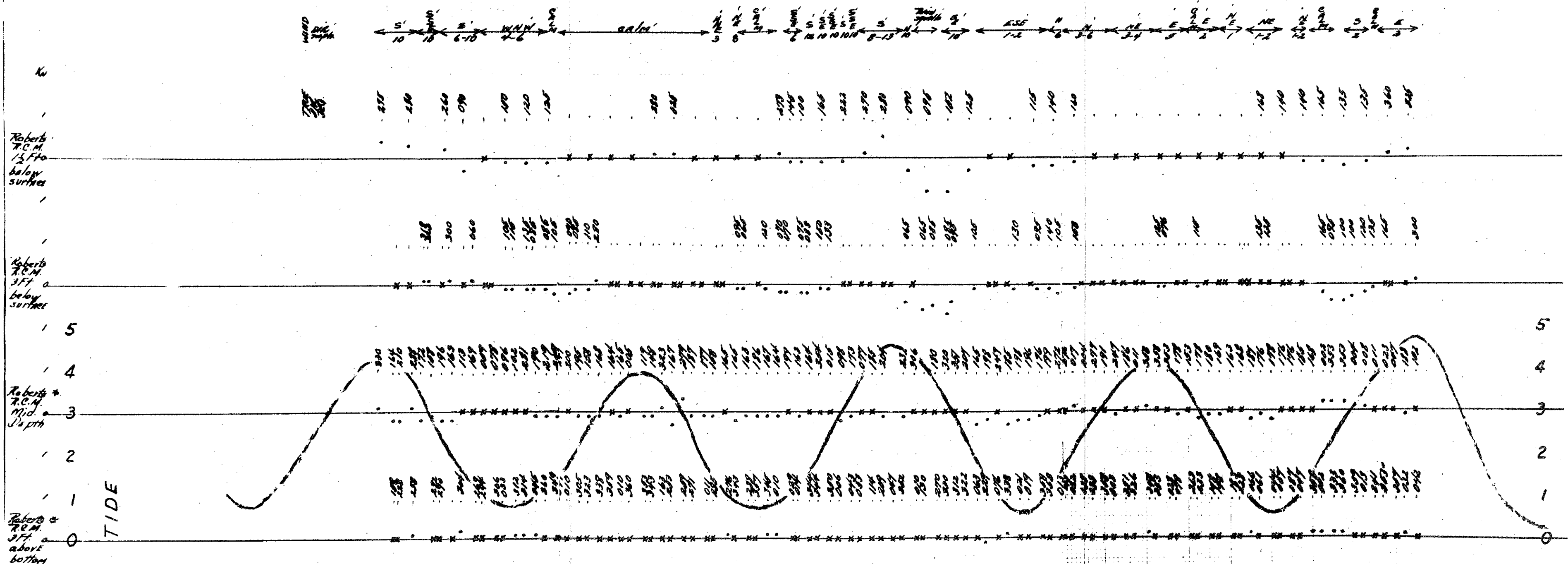


NOTES:

Data on intake and discharge water temperatures, on temperature and power output and condenser tube failures furnished by New England Power Co. on hourly basis.
 @ - Temperatures 3 ft. above river bottom at Slatkoff River and at points opposite intake.
 Dates on river water temperatures obtained by U.S. Coast and Geodetic Survey.

REVISION	DATE	DESCRIPTION	BY
U.S. ARMY ENGINEER DIVISION, NEW ENGLAND CORPS OF ENGINEERS WALTHAM, MASS.			
DES. BY	SK. BY	CHK. BY	
PROJECT ENGINEER			
APPROVAL RECOMMENDED			
APPROVED			
CHIEF, R.E.D. BRANCH			
CHIEF, ENGINEERING DIVISION			
SCALE: NO SCALE			SPEC. NO.
DRAWING NUMBER			
FP-1-1018			
SHEET 4			

Providence, Rhode Island
 759
 1-14-28
 SSW of Fox Point, Providence River
 H.W. Keith, Jr.
 Lat 41° 48' 49" Long 71° 34' 05" W
 T.M. 60° W
 Chart 262
 Providence River
 H.W. Keith, Jr.
 T.M. 60° W
 Providence River
 H.W. Keith, Jr.
 T.M. 60° W

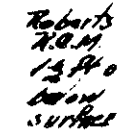


* At mid-depth and 3 ft above the bottom, directions were obtained with a special vane-type direction indicator.

PLATE NO. 13-5a

plotted 22/10/59
 VBY DAD 10-8-59

1959
Aug. 30



Robert's
T.D.A.
244 0
below
surface

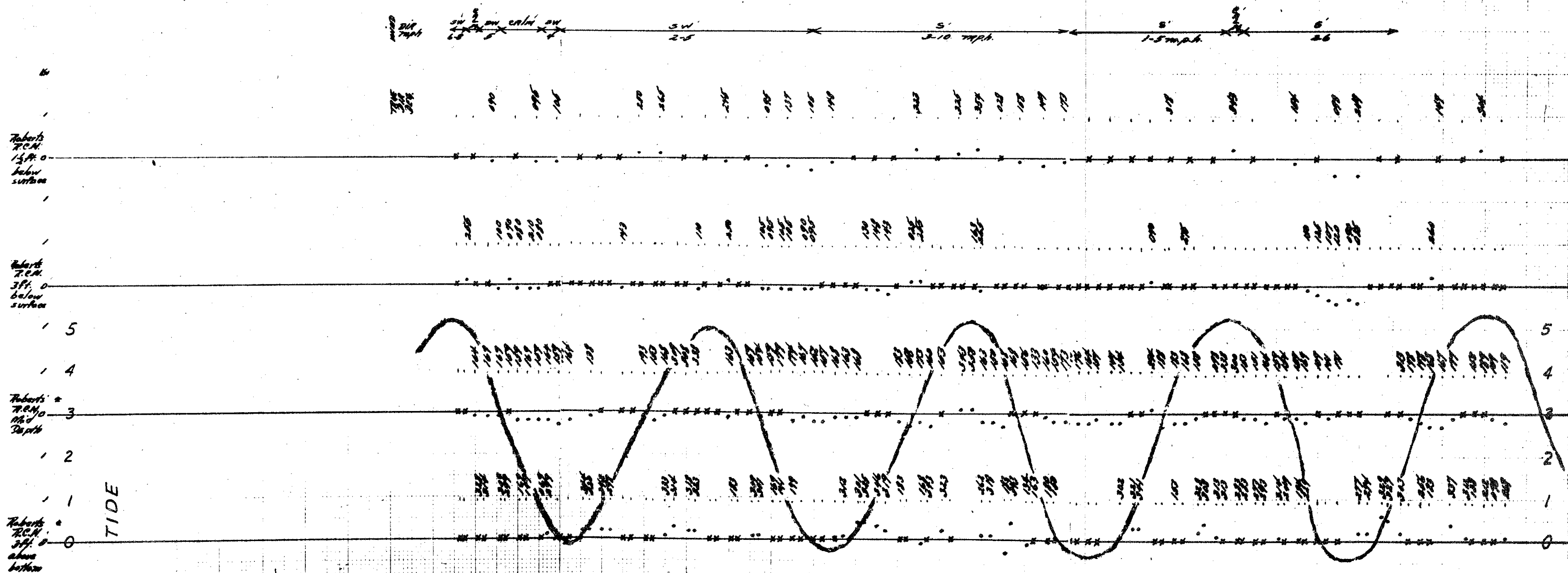
Labels
T.C.M.
Mid O.
Depth

Ref. 1
2. C. H.
3. H. A.
about
bottom

At mid-depth and 3 feet above the bottom, directions were obtained with a special vane-type direction indicator.

PLATE NO. 13-5b
 plotted REAP 10/15/59
 UCAU 10-8-59

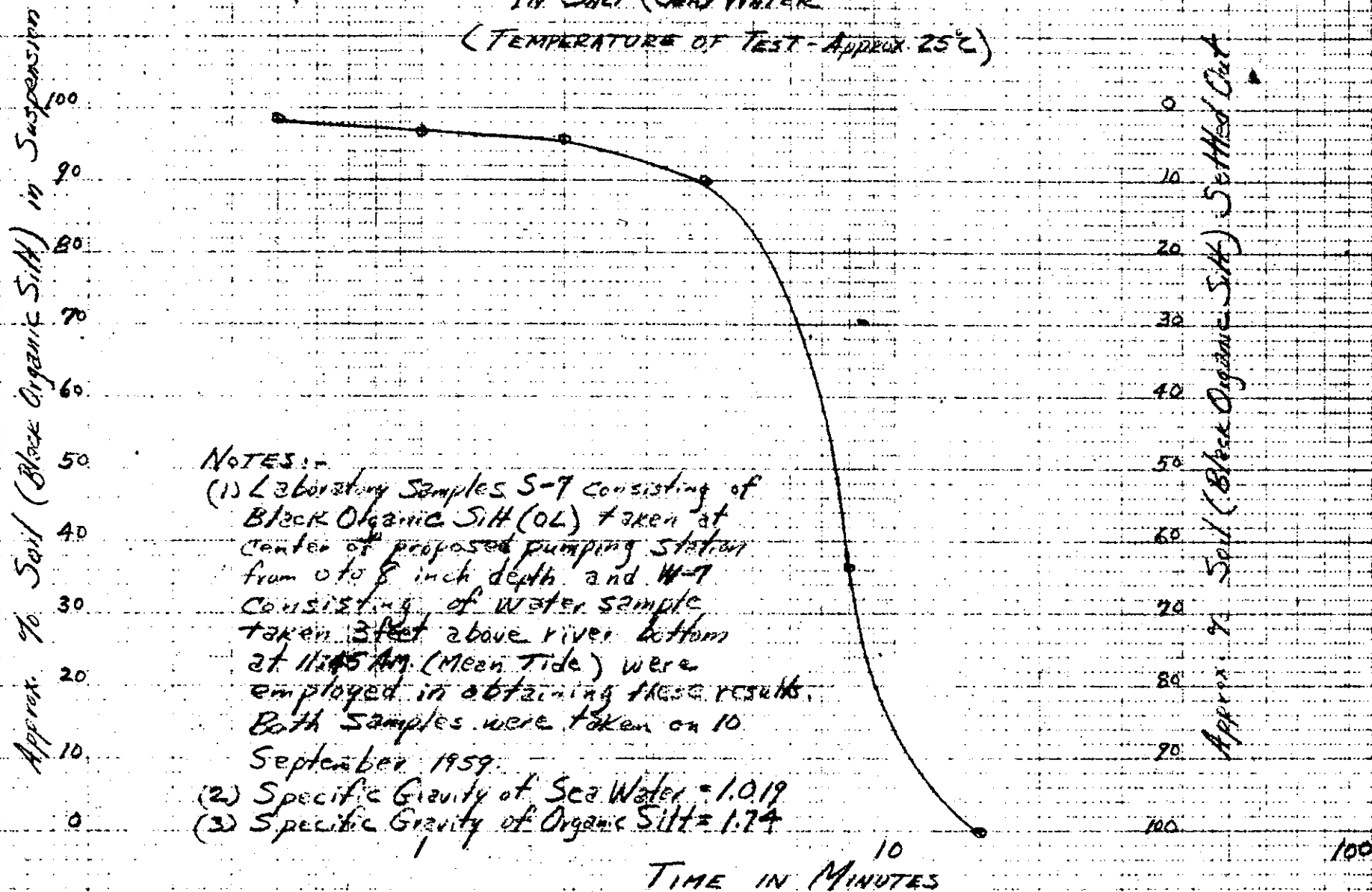
Providence, Rhode Island Lat. 41°49'08"N Long. 71°24'19"W
 1959 3 NW of Swing Bridge, Providence River Chart 352 H.W. Keith, Jr. T.M. 60°W
 Sept. 1 Providence River H.W. Keith, Jr. T.M. 60°W



* At mid-depth and 3 ft above the bottom, directions were obtained with a special mini-type indicator

PLATE NO. 13-5c
 plotted SEP 10/1959
 VDAD 10-9-59

FOX POINT HURRICANE BARRIER
PERCENT BLACK ORGANIC SILT VS. TIME OF SETTLING
IN SALT (SEA) WATER
 (TEMPERATURE OF TEST - APPROX. 25°C)



NOTES:-

- (1) Laboratory Samples S-7 consisting of Black Organic Silt (OL) taken at center of proposed pumping station from 0 to 8 inch depth and W-7 consisting of water sample taken 3 feet above river bottom at 11:45 AM (Mean Tide) were employed in obtaining these results. Both samples were taken on 10 September 1959.

- (2) Specific Gravity of Sea Water = 1.019
- (3) Specific Gravity of Organic Silt = 1.74

NEW ENGLAND POWER SERVICE COMPANY



441 STUART STREET, BOSTON 16, MASS.

November 16, 1959

U.S. Army Engineer Division, New England
Corps of Engineers
424 Trapelo Road
Waltham 54, Massachusetts

Attention: Mr. R.S. Martin

Re. Fox Point Hurricane Barrier
Providence, Rhode Island

Dear Sir:

In response to your recent inquiry regarding the composition of the condenser tubes at our generating stations in Providence, there are several different alloys being used at the present time. Those now being used most extensively include the following:

70-30 Cupro-Nickel (High Iron)
90-10 Cupro-Nickel (High Iron)
Arsenical Aluminum Brass
Phosphorized Aluminum Brass

Very truly yours,

NEW ENGLAND POWER SERVICE COMPANY

D. R. Campbell
D. R. Campbell

DRC:mj

EXHIBIT
NO. 13-7

Werby

LABORATORIES • INC.

Consulting and Analytical Chemists

88 Broad Street • Boston 10 • Massachusetts • Liberty 2-6739

November 16, 1959

Soils Laboratory
U.S. Army Engineer Division,
New England
Corps of Engineers
424 Trapelo Road
Waltham 54, Massachusetts

Gentlemen:

This letter will serve to confirm some of the opinions I have offered verbally in conversations with you in the course of a program of chemical and bacteriological analyses of water and soil samples from Fox Point. This work was performed under Order No. NEDSP-60-213.

The salinity of all water samples studied was extremely high - and, in our opinion, this characteristic would be the most significant factor tending to make the water corrosive.

Many other factors, of course, enter into the picture when one contemplates the possible corrosive action of a given water source. Therefore, except by detailed study of all possible factors - including topography, tide conditions, temperatures prevailing, as well as the exact composition of metals likely to be in contact with such a water - one can make only superficial comments.

However, another source of possible difficulty, are sulfides. The chemistry of sulfur compounds is, in itself, complex, and in a given system, conditions usually prevailing (particularly in the case of tidal waters such as those examined) make for dynamic rather than static characteristics. Therefore, there will be a tendency for sulfides present at a given time to disappear. Likewise, the availability of sulfates (the waters are high in this factor) and the possibility of presence of bacteria capable of reducing sulfates - and producing sulfides thereby - will be a possible source of increasing the sulfide content of the water.

EXHIBIT
NO. 13-8a

Werby

LABORATORIES • INC.

Consulting and Analytical Chemists

88 Broad Street • Boston 10 • Massachusetts • Liberty 2-0739

Soils Laboratory, U. S. Army Engineer Division

Nov. 16, 1959

Page 2

Accordingly, it is not at all possible to make an estimate as to how long sulfides, once formed, would remain in the water. Several factors would tend to decrease these sulfides with the passage of time. These are (1) oxidation of sulfides to higher forms of sulfur, (2) Precipitation of soluble sulfides from solution by combining with dissolved metals to form insoluble sulfides, (3) release from the water by volatilization as hydrogen sulfide gas.

As mentioned above, the presence of sulfate-reducing bacteria may lead to an increase in sulfides (while other mechanisms are tending to produce a decrease). However, it is believed significant in this respect that - of all water samples investigated - only the purposely site-agitated and laboratory-agitated samples showed these organisms present; and only in relatively limited amounts. It is also interesting to note that these organisms are extremely slow acting (in laboratory evaluation, one must wait for over four weeks before being able to "read" the specimens).

From these considerations, it would not seem likely that sulfides in the water will be a very great factor in the corrosive properties of the system. Certainly, the relatively huge amount of chlorides present would seem to have a far greater potential for corrosive damage. It should be noted that positive values for sulfides were only found in three of the water specimens; in these the level was below one part per million. Moreover, two of these three samples had been purposely agitated with "muck". And, further, the small values found were as total sulfides, and included, therefore, insoluble as well as soluble sulfides.

Very truly yours,

WERBY LABORATORIES, Inc.

Russell T. Werby, Manager

EXHIBIT
NO. 13-86



LABORATORIES • INC.

Consulting and Analytical Chemists

88 Broad Street • Boston 10 • Massachusetts • Liberty 2-0739

LEGEND FOR FOX POINT WATER AND SOIL SAMPLES

(Taken Along Center Line Proposed Barrier - PHS Sta. 27/00)

Laboratory
Sample No.

Description

W-1	Water sample taken 3' down from surface of water at 7:49 A.M. (Low Tide) on 27 August 1959.
W-2	Water sample taken 3' up from river bottom at 7:49 A.M. (Low Tide) on 27 August 1959.
W-3	Water sample taken 3' down from surface of water at 11:43 A.M. (Mean Tide) on 27 August 1959.
W-4	Water sample taken 3' up from river bottom at 11:43 A.M. (Mean Tide) on 27 August 1959.
W-5	Water sample taken 3' down from surface of water at 3:28 P.M. (High Tide) on 27 August 1959.
W-6	Water sample taken 3' up from river bottom at 3:28 P.M. (High Tide) on 27 August 1959.
W-7	Water sample taken 3' up from river bottom at 11:45 A.M. (Mean Tide) on 10 September 1959.
W-8	Water sample taken 1' $\frac{1}{2}$ up from river bottom at 11:55 A.M. (Mean Tide) on 10 September 1959 after agitating river bottom with sample container.
W-9	Mixture of water sample W-7 and Organic Silt (Muck) sample (3-7) in the laboratory, in the amount of one quart Organic Silt and one gallon water. Analytical samples taken after one-half hour's standing.
S-1	Black organic silt (OL) sample taken at 9:45 A.M., 27 August 1959 from 0-8" depth, 30 feet east of pier at Narragansett Electric Light Company. Represents individual samples J1, J2, JA, and JB of same material taken for specific test purposes from exploration M-1.

EXHIBIT
NO. 13-8c



LABORATORIES • INC.

Consulting and Analytical Chemists

88 Broad Street • Boston 10 • Massachusetts • Liberty 2-0739

LEGEND FOR FOX POINT WATER AND SOIL SAMPLES (Page 2)

Laboratory
Sample No.

Description

- S-2 Black Organic Silt (OL) sample taken at 10:10 A.M. 27 August 1959 from 0-8" depth, 25 feet west of pier at D & R Box Company Warehouse. Represents individual samples J1, J2, JC, and JD of same material taken for specific test purposes from exploration M-2.
- S-3 Black Organic Silt (OL) sample taken at 10:20 A.M. 28 August 1959 from 0-8" depth, 270 feet east of pier at Narragansett Electric Light Company. Represents individual samples J1, J2, JE, and JF of same material taken for specific test purposes from exploration M-3.
- S-4 Gray Sandy Organic Silt (OL) sample taken at 1:20 P.M. 28 August 1959 from 6.0 to 7.0 foot depth, 270 feet east of pier at Narragansett Electric Light Company. Represents individual samples J3, J4, JG, and JH of same material taken for specific test purposes from exploration M-3.
- S-5 Gray Sandy Organic Silt (OL) sample taken at 3:15 P.M., 28 August 1959 from 9.5 to 10.5 foot depth, 270 feet east of pier at Narragansett Electric Light Company. Represents individual samples J5, J6, JJ, and JK of same material taken for specific test purposes from exploration M-3.
- S-6 Gray Sandy Organic Silt (OL) sample taken at 3:15 P.M., 28 August 1959 from 12.0 to 13.0 foot depth, 270 feet east of pier at Narragansett Electric Light Company. Represents individual samples J7, J8, JL, and JM of same material taken for specific test purposes from exploration M-3.
- S-7 Black Organic Silt (OL) sample taken at 12:15 P.M., 10 September 1959 from 0 to 8 inch depth, at center of proposed pumping station (location of FD-49). Represents individual samples J1, JN, JO, JP and JQ of same material taken for specific test purposes from exploration M-4.

EXHIBIT
NO. 13-8d

RESULTS OF ANALYSES OF FOX POINT WATER SAMPLES

	W-1	W-2	W-3	W-4	W-5	W-6	W-7	W-8	W-9
pH	7.4	7.4	7.9	7.3	8.3	7.6	7.4	7.3	7.3
Turbidity, ppm.	40	3	50	2	70	8	2	40	210
Free Carbon Dioxide, ppm.	11.5	14.0	2.0	12.0	0.0	6.5	12.0	12.0	10.8
Alkalinity as CaCO ₃ :									
Total, ppm.	98	100	96	105	97	103	107	105	108
Carbonate, ppm.	0	0	0	0	23	0	0	0	0
Bicarbonate, ppm.	98	100	96	105	74	103	107	105	108
Hydroxide, ppm.	0	0	0	0	0	0	0	0	0
Free Mineral Acid, ppm.	0	0	0	0	0	0	0	0	0
Total Hardness as CaCO ₃ , ppm.	4000	5250	4200	5550	4600	5000	5310	5330	5320
Ferrous Iron, Total, ppm.	0	0	0	0	0	0	0	0	0
Ferric Iron :									
Total, ppm.	0.44	0.28	0.44	0.20	0.40	0.30	0.32	0.35	0.37
Dissolved, ppm.	0.02	0.02	0.02	0.02	0.04	0.02	0.03	0.03	0.03
Suspended, ppm.	0.42	0.26	0.42	0.18	0.36	0.28	0.29	0.32	0.34
Sulfides as S ⁻ , Total, ppm.	-0.05	-0.05	-0.05	-0.05	-0.05	-0.05	0.32	0.62	0.84
Silica, ppm.	2.2	3.2	1.0	1.6	1.0	0.04	1.8	1.8	1.8
Sulfates, ppm.	1750	2310	1880	2290	1980	2230	2270	2270	2280
Chlorides, ppm.	12,750	16,870	13,650	16,890	14,500	16,150	16,510	16,560	16,500
Manganese, ppm.	0	0	0	0	0	0	0	0	0
Staining Properties, CRD-C401	Severe	Severe	Severe	Severe	Severe	Severe	Severe	Severe	Severe
Free Ammonia as N, ppm.	0.214	0.244	0.130	0.244	0.004	0.110	0.281	0.263	0.250
Oil, ppm.	0	0	0	0	0	0	0	0	0
Solids :									
Total, ppm.	23,520	31,200	25,370	32,650	27,980	31,720	32,500	32,620	32,780
Dissolved, ppm.	23,350	30,880	25,240	32,380	27,790	31,510	32,310	32,040	31,990
Suspended, ppm.	170	320	130	270	190	210	190	580	790
Loss on Ignition, ppm.	1200	1400	1300	1350	1420	1870	1240	1380	1420
Specific Conductance, mhos per cm.	0.025	0.031	0.025	0.032	0.028	0.033	0.033	0.032	0.032
Sulfate-Reducing Bacteria, Most Probable Number per 100 ml.	None Detected	None Detected	None Detected	None Detected	None Detected	None Detected	None Detected	None Detected	None Detected

³ EXHIBIT ³
 NO. 13-8e

Werby

LABORATORIES • INC.
Consulting and Analytical Chemists

88 Broad Street • Boston 10 • Massachusetts • Liberty 2-0739

RESULTS OF ANALYSES OF FOX POINT SOIL SAMPLES

	<u>S-1</u>	<u>S-2</u>	<u>S-3</u>	<u>S-4</u>	<u>S-5</u>	<u>S-6</u>	<u>S-7</u>
<u>Basis, Original Sample Received</u>							
pH	7.8	7.8	7.2	3.8	3.6	3.2	7.6
Loss on Drying, %	66.70	63.28	69.62	32.89	33.40	25.73	64.07

<u>Basis, Laboratory-Dried Sample</u>							
Loss on Ignition, %	22.78	17.62	18.61	5.45	5.68	4.67	18.15
Organic Matter, Titration Method, %	17.12	13.78	15.85	3.27	3.66	2.34	14.26
Iron, %	4.10	3.86	4.19	2.96	3.18	3.10	4.32
Manganese, %	0.08	0.11	0.09	0.07	0.07	0.05	0.13
Oil, %	1.78	1.39	1.52	0.09	0.12	0.0	1.71
Total Sulfides as S ⁼ , in milligrams per gram	1.15	1.88	1.89	-0.0025	-0.0025	-0.0025	1.76
Sulfate-Reducing Bacteria, Most Probable Number per 100 ml.	> 1100	> 1100	> 1100	> 240	> 240	23	> 1100

EXHIBIT
NO. 13-8f